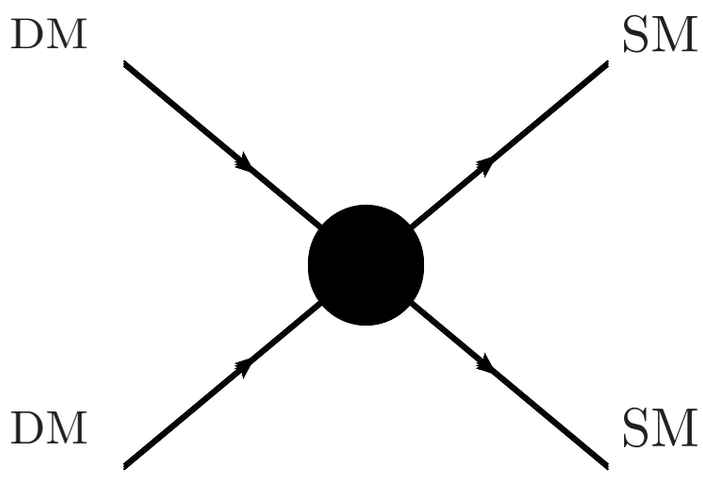
Opportunities to look for a light Dark Sector

Eder Izaguirre

A Thermal Origin

Suppose DM was in thermal equilibrium with SM



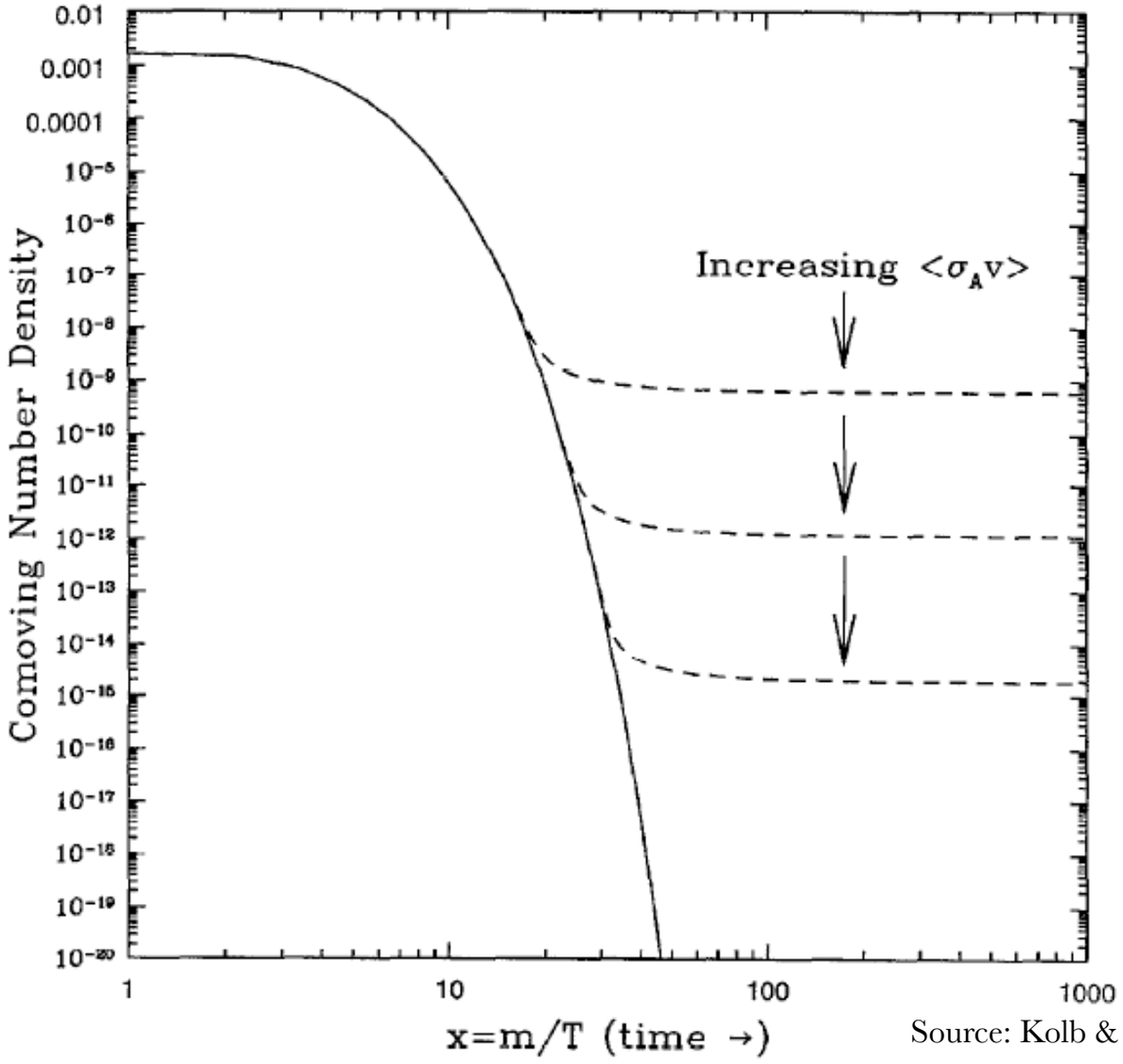
$$\Gamma = n\sigma v$$

Thermal equilibrium will cease when

$$\Gamma < \Gamma_H$$

After this point, DM is “frozen out”

A Thermal Origin



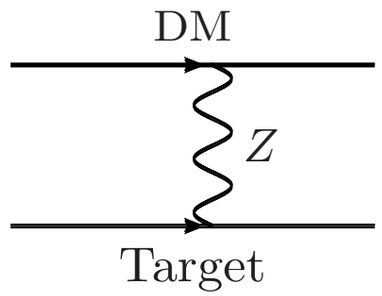
Source: Kolb & Turner

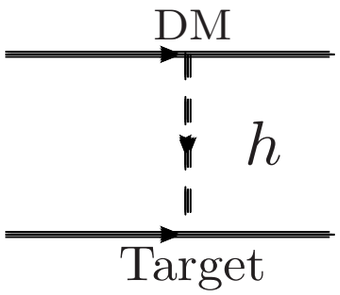
To get today's DM abundance need

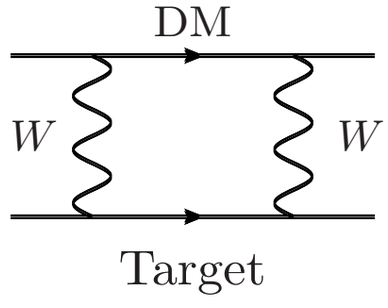
$$\langle \sigma v \rangle \sim 3 \times 10^{-26} \frac{\mathrm{cm}^3}{\mathrm{s}}$$

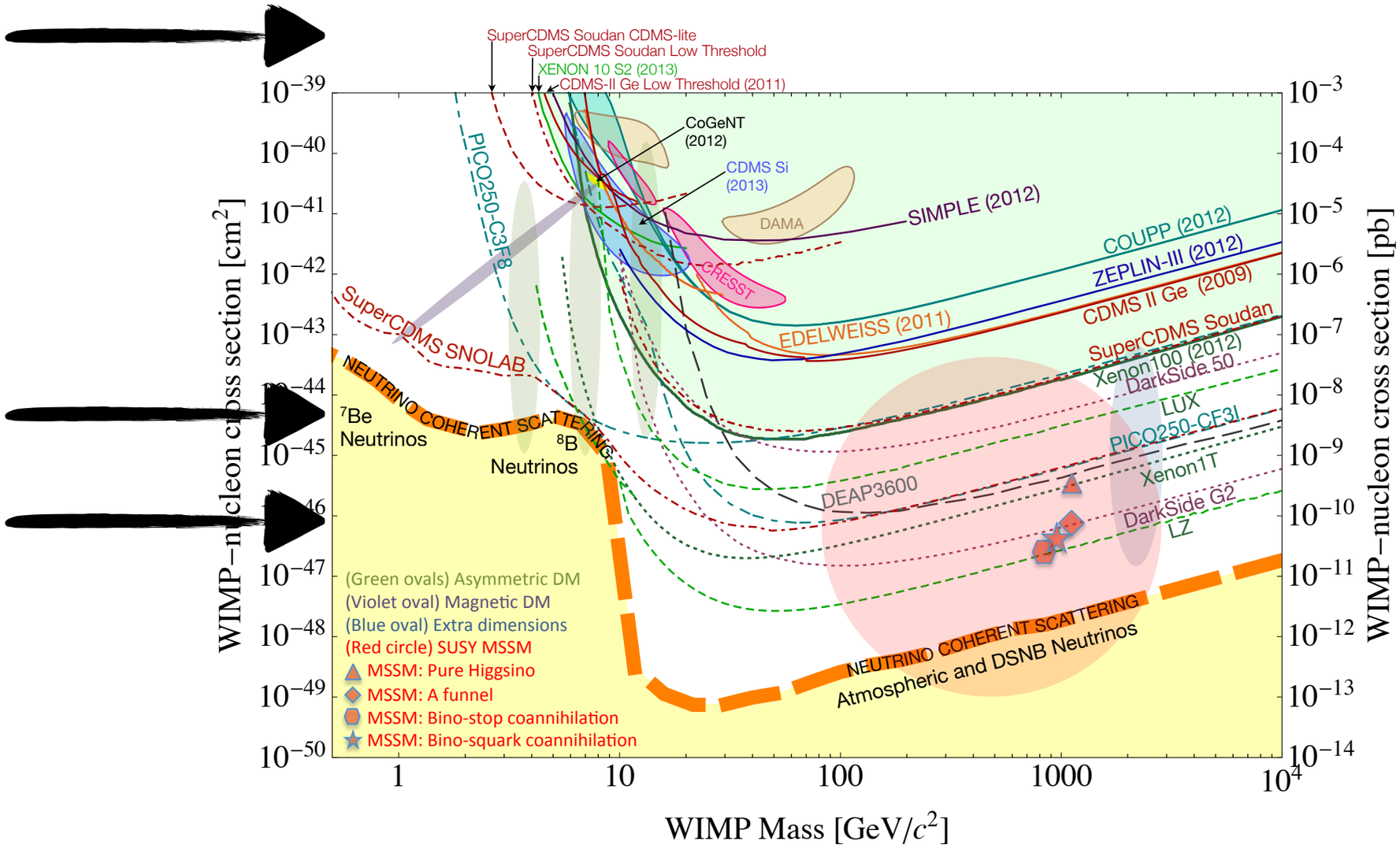
Thermal origin is a broad paradigm
Suggests non-gravitational interactions between DM and SM

Status of Dark Matter Searches





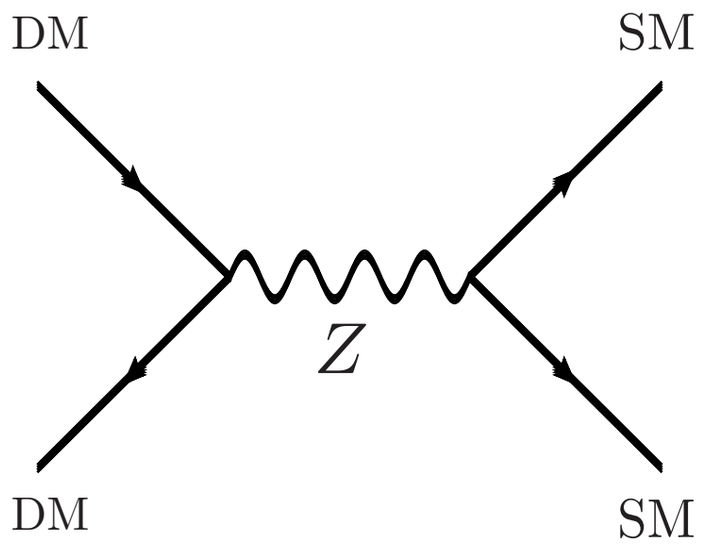




Thermal DM

Could DM be lighter than conventional WIMPs?

Imagine DM's mass is 10 MeV



$$\langle \sigma v \rangle \propto \frac{(g_D g_{\rm SM})^2 m_{\rm DM}^2}{m_Z^4}$$

$$\langle \sigma v \rangle \ll 3 \times 10^{-26} \frac{\rm cm^3}{\rm s}$$

$$\rho_{\rm DM} \gg \rho_{\rm observed}$$

Thermal DM

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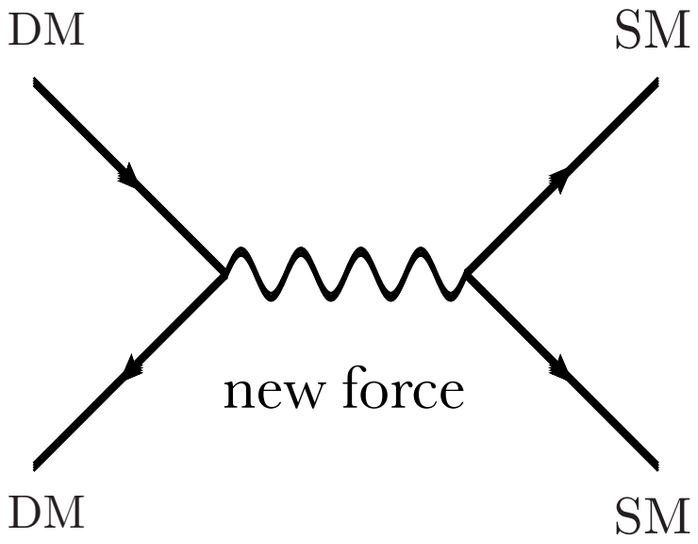


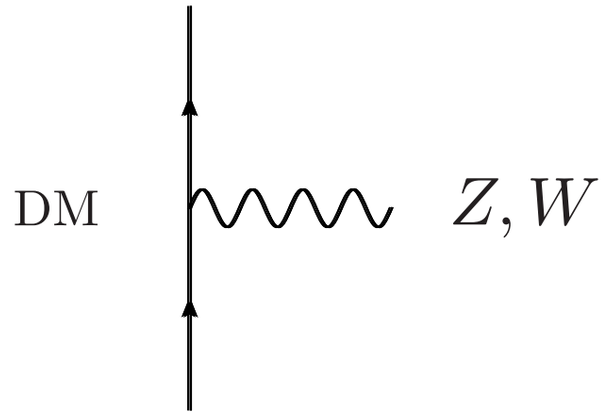
$$\langle \sigma v \rangle \propto \frac{(g_D g_{\rm SM})^2 m_{\rm DM}^2}{m_{\rm mediator}^4}$$

$$m_{\rm mediator} \ll m_Z$$

$$\rho_{\rm DM} = \rho_{\rm observed}$$

Two Simple Possibilities

Primarily looked for DM charged under **known** forces



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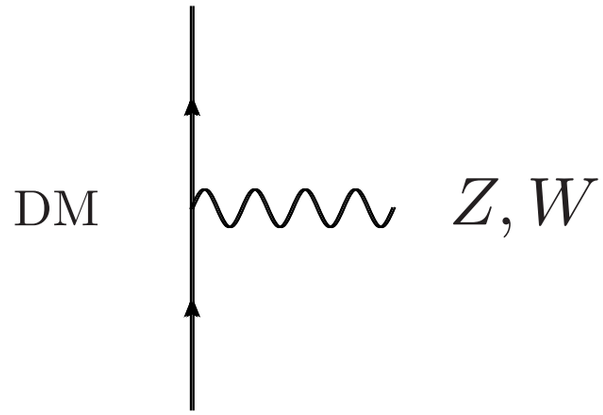
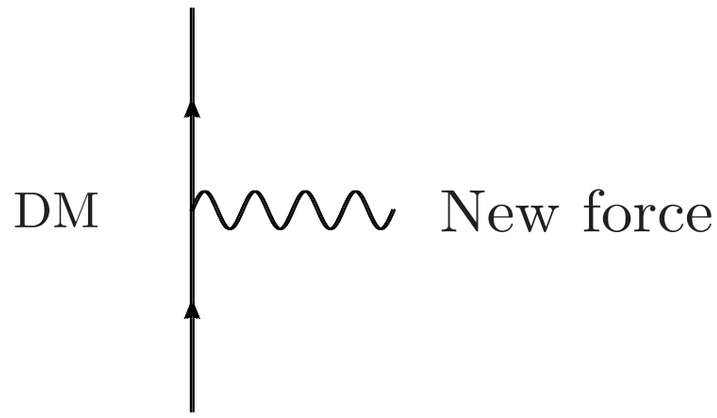
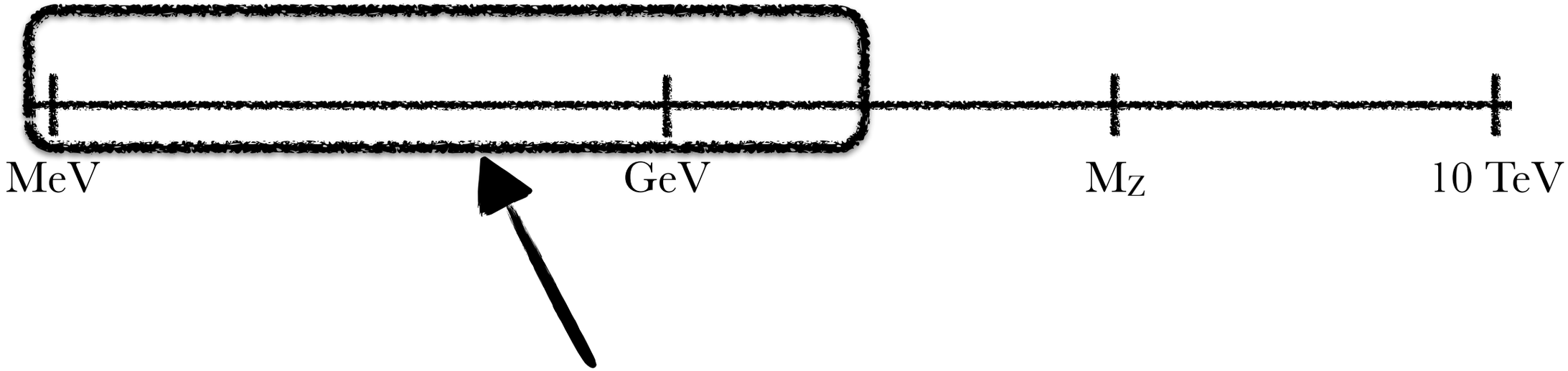


What about the other possibility?
DM charged under **new** force



A Thermal Origin

A thermal origin gives us a restricted sharp target to aim for

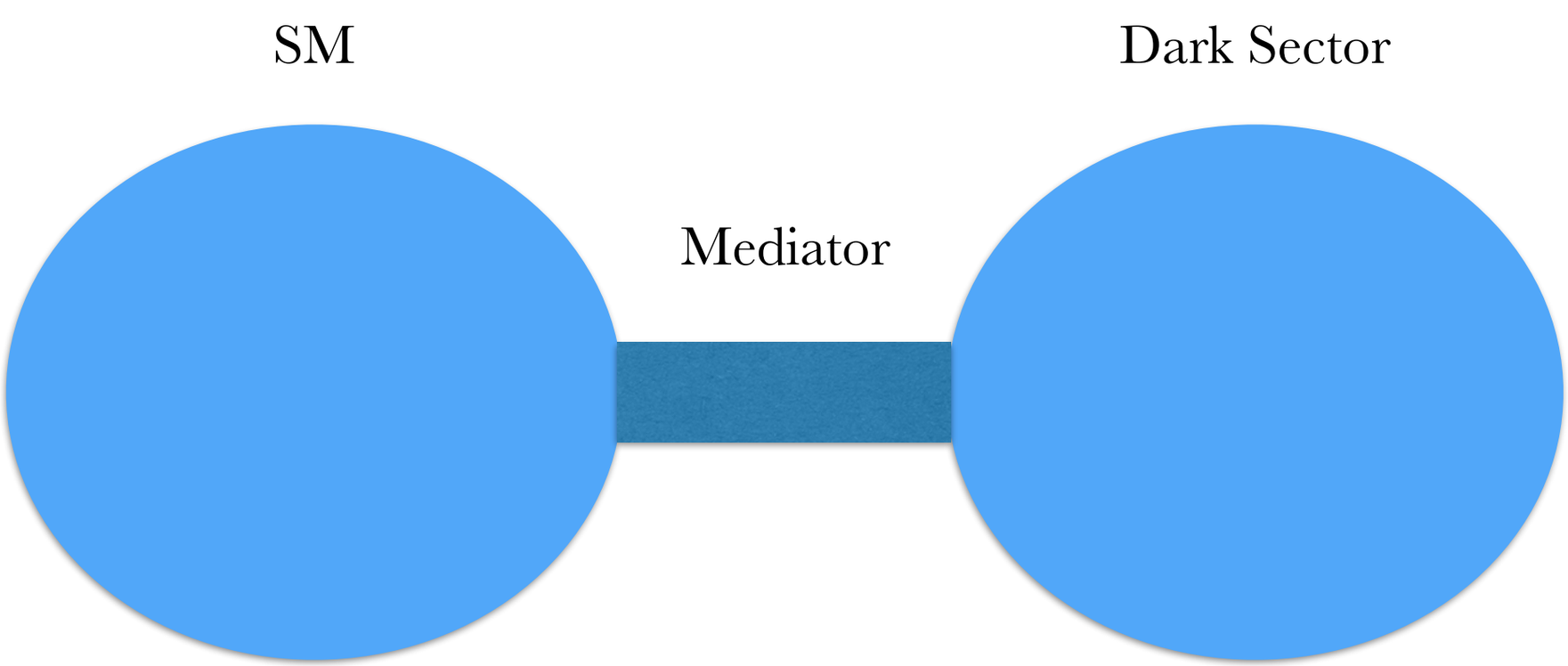


Light DM necessarily requires a new force!

A Broader Hidden Sector Paradigm

Beyond the SM physics that lives in a "dark sector"

A new force/interaction connects the SM to a Dark Sector (DS)



What are the "simplest" (renormalizable) allowed interactions between the SM and the DS?

M_0

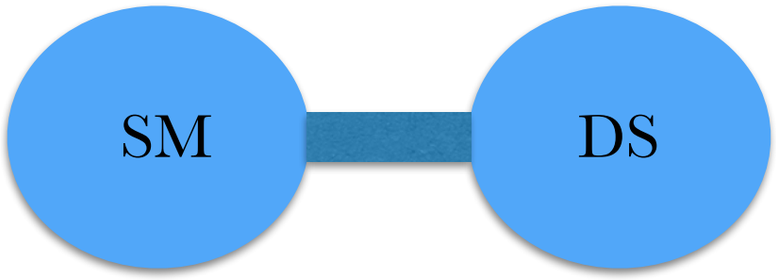
The Most Minimal Interactions

Vector Portal (spin 1) $\epsilon_Y B^{\mu\nu} F'_{\mu\nu}$

Scalar Portal (spin 0) $\epsilon_h |h|^2 |\phi|^2$

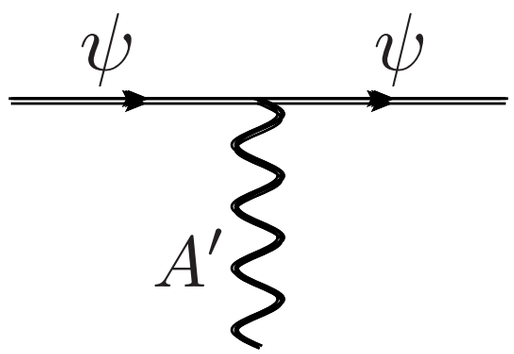
Fermion Portal (spin 1/2) $\epsilon_\nu L h \psi$

Matter Residing in the Dark Sector

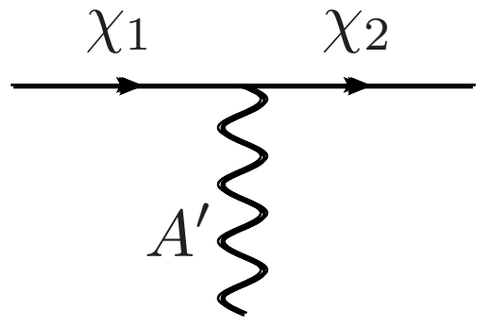


Suppose DS matter is fermionic (lesson applicable to spin 0)

Dirac-like matter



Majorana-like matter



$m_1 < m_2$

χ_2 is unstable

The Vector Portal

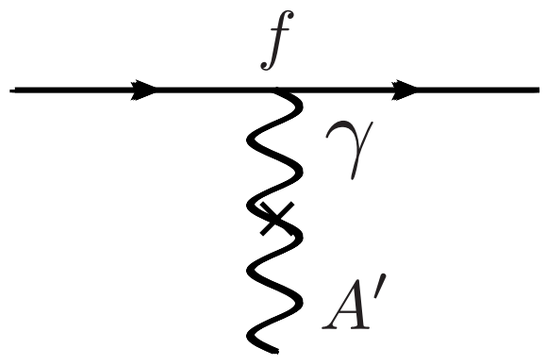
Distinct phases of the theory
Each with difference phenomenology consequences

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} - \frac{1}{4} F'^{\mu\nu} F'_{\mu\nu} - \frac{\kappa}{2} F'^{\mu\nu} B_{\mu\nu} + \frac{1}{2} m^2_{A'} A'^{\mu} A'_{\mu}$$

The massive phase

$m'_A \neq 0$

SM fermions acquire a small charge
under a short-range force
mediated by the “dark photon”!



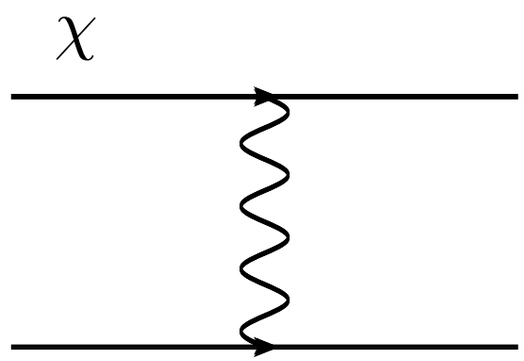
$Q_D \approx \kappa \cos\theta_W e$
$\equiv \epsilon e$

While dark fermions remain neutral under EM

Summary of Dark Sector Workshop from April 2016

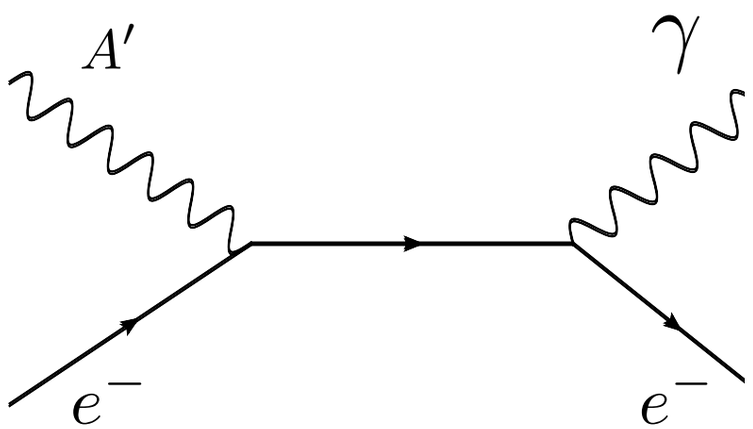
Two main approaches to look for light DM
Accelerators and Direct Detection

Some overlap between the two

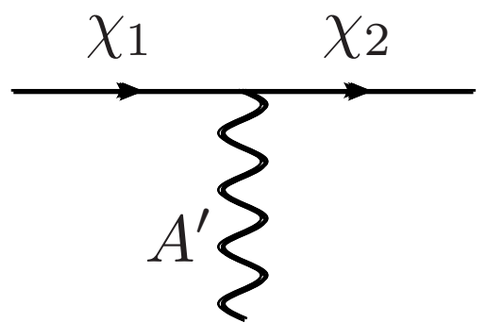


Each has their own strengths too

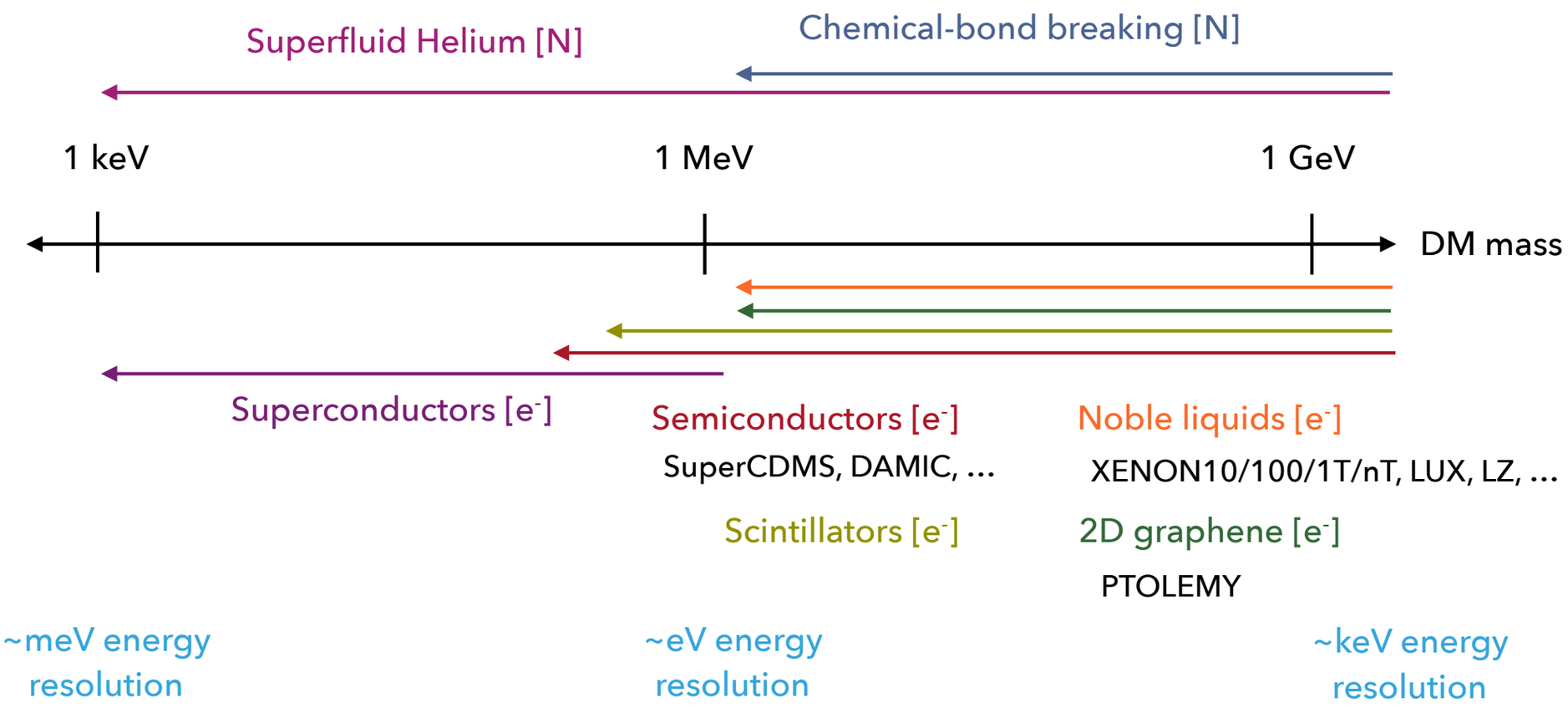
Ultralight DM at direct detection



Majorana DM at accelerators

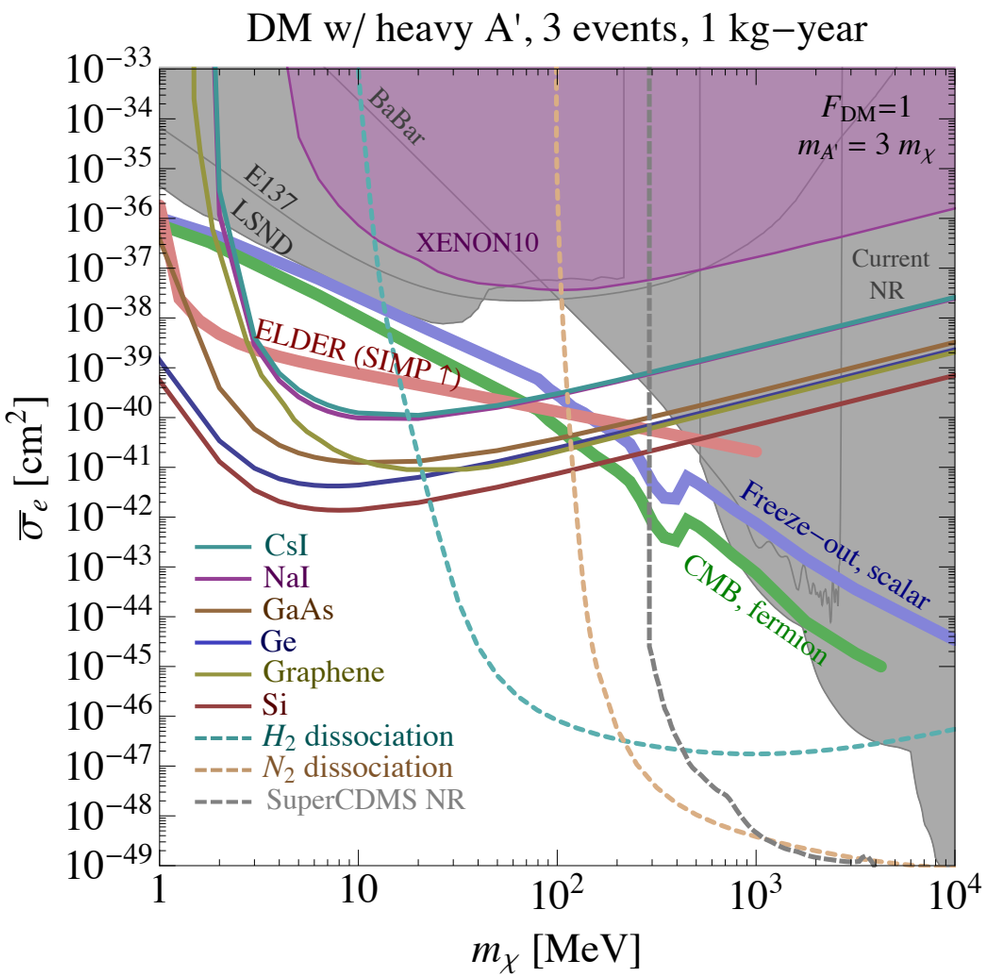


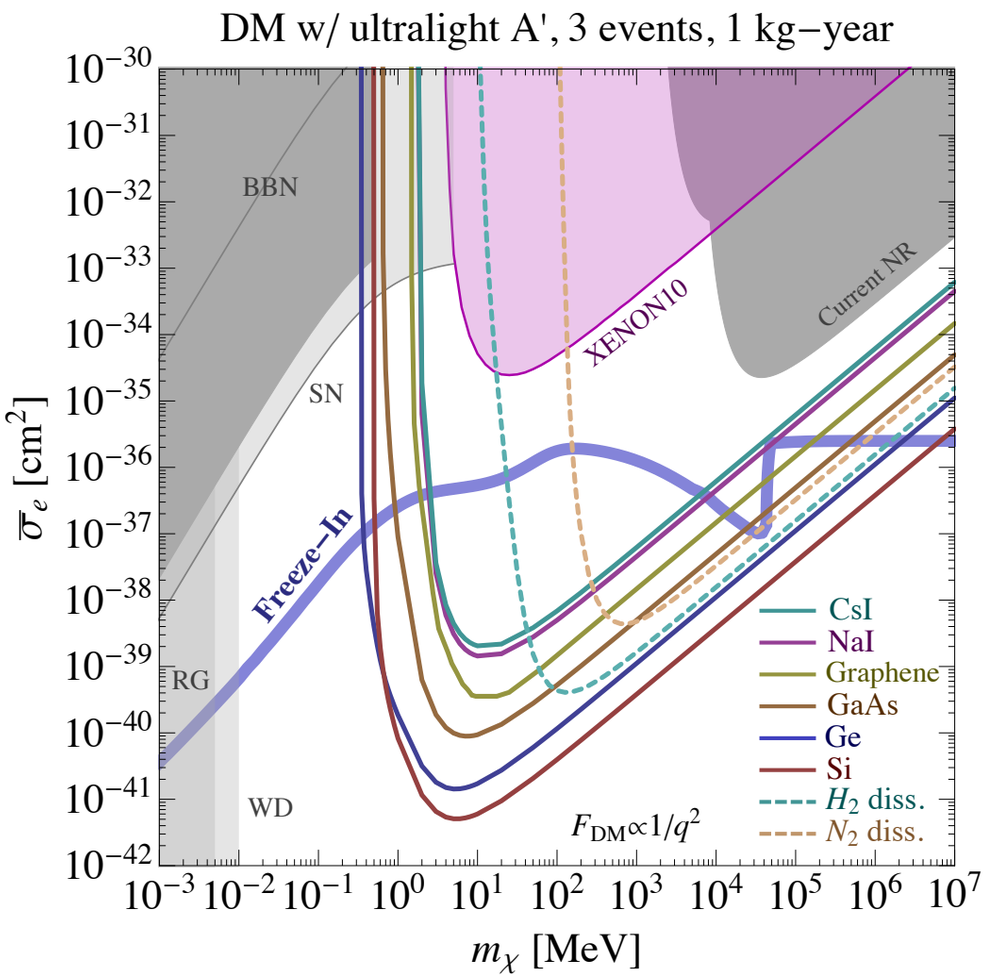
Direct Detection



To date: re-analysis of old data by DAMIC and Xenon10

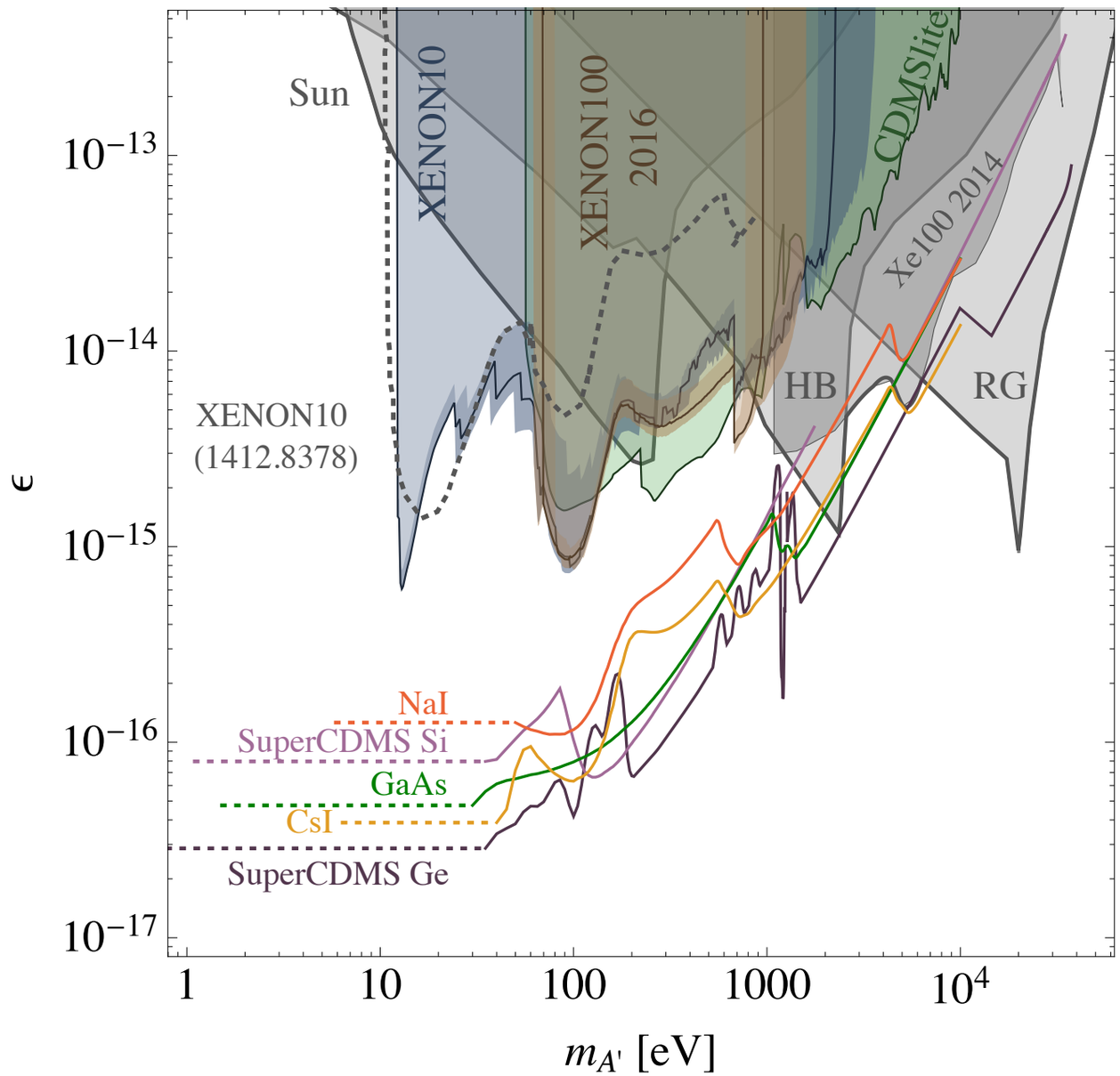
Direct Detection





Scattering

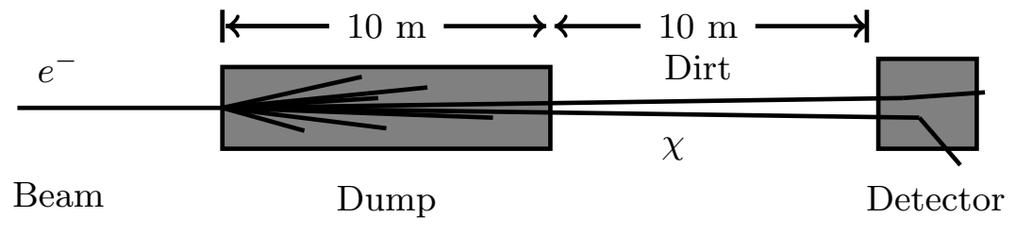
Direct Detection



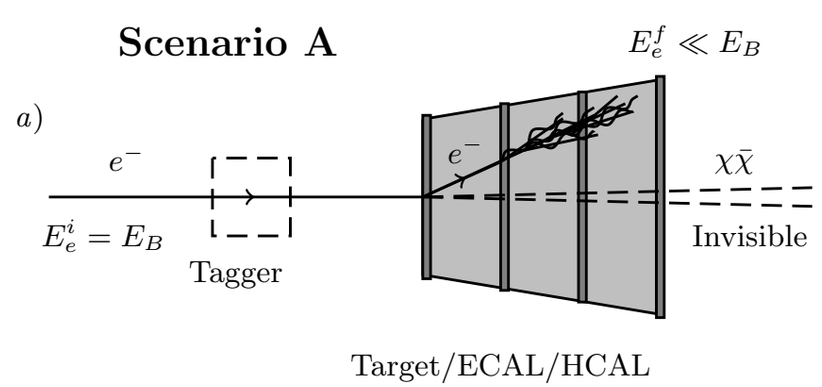
Absorption (1608.02123)

Accelerators

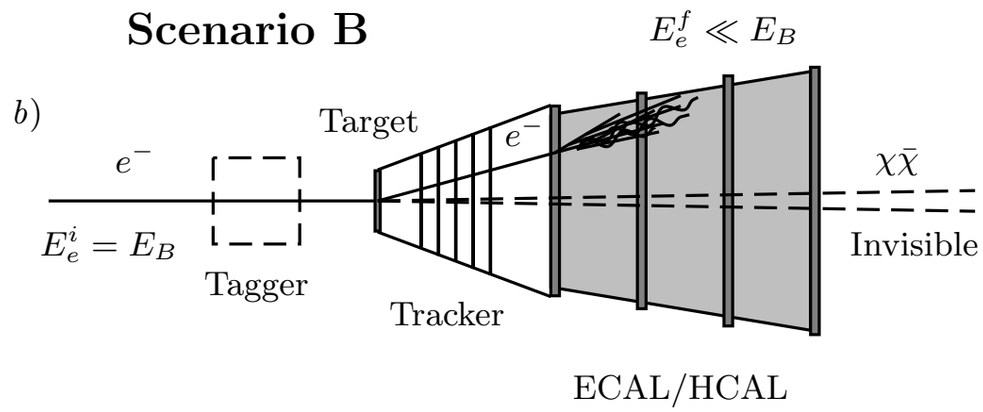
Electron beam-dump experiment
BDX proposal at JLab



Electron missing energy
NA64 at CERN



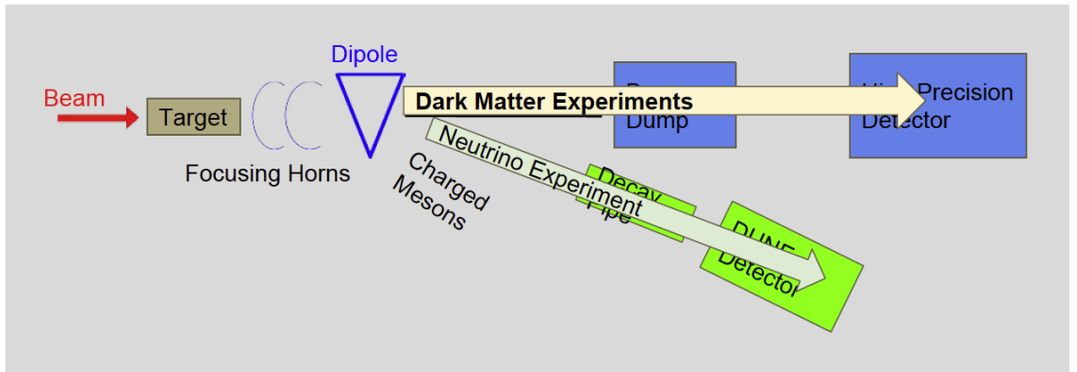
Missing momentum at SLAC



Accelerators

Proof of principle ongoing at Miniboone

Proton beam-dump experiments
FNAL



Accelerators